APPLICATION
FOR
UNITED STATES PATENT

TITLE OF INVENTION

LOW DENSITY NONWOVEN GLASS FIBER WEB

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LOW DENSITY NONWOVEN GLASS FIBER WEB

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Patent Application Serial No. 60/463,870, filed on April 18, 2003, entitled "Low Density Nonwoven Glass Fiber Web," which is expressly incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to filter media formed of or containing nonwoven glass fiber webs, and in particular to methods of forming nonwoven glass fiber webs having enhanced filtration performance characteristics.

BACKGROUND OF THE INVENTION

[0003] Glass fiber mats are used for a variety of purposes, including, for example, in battery separators, air and water filters, vacuum bags, automobile air conditioning filters, and indoor air cleaner filters. The two most common methods for producing glass fiber mats are dry laid processing and wet laid processing. In a dry laid process the glass fibers are chopped and dispersed in air that is blown onto a conveyor, and a binder is then applied to form a mat. Such a process is typically more suitable for the production of highly porous mats having bundles of glass fibers. In a wet laid process, a slurry is formed containing the glass fibers, and optionally other chemical agents such as dispersants, viscosity modifiers, and defoaming agents. Glass fibers are anionic by nature, and thus the acidic slurry is used to remove any charge present on the fibers to disperse the fibers from the glass wool conglomeration. As a result, the frictional contact between the fibers is increased and the processability of the fibers is improved. The fibers from the slurry are then collected on a screen which allows a substantial portion of the water from the slurry to be drained. The resulting mat is then dried to yield a nonwoven mat formed of glass fibers.

[0004] A major objective of wet laid nonwoven manufacturing is to produce materials with textile-fabric characteristics, primarily flexibility and strength, at speeds approaching those

associated with papermaking. Current processes, however, tend to affect filtration properties, producing nonwoven webs that have a high density with high resistance.

[0005] Accordingly, there is a need for improved glass fiber webs, filter media containing glass fiber webs, and methods for making the same.

SUMMARY OF THE INVENTION

[0006] In general, the present invention provides nonwoven filter media formed of or containing glass fiber webs, and methods for making the same. In one embodiment, a nonwoven filter media is formed of or contains at least one glass wool fiber web and has a gamma value of at least about 14, a surface area of at least about 1.2 m^2/g, and/or an apparent density of at least about 0.15 g/cc. The glass wool fibers that form the glass wool fiber web preferably have a diameter in the range of about 0.1μ to 4.5μ, and more preferably the diameter of the fibers is in the range of about 0.3μ to 4.5μ. In an exemplary embodiment, the glass wool fiber web is formed from glass wool fibers having a diameter of about 0.69μ and/or 4.5μ. The glass wool fibers can also optionally be combined with chopped wool fibers.

[0007] In another embodiment, a filter media is provided having a support layer, and a filtration layer including glass wool fibers having a diameter in the range of about 0.1μ to 3.5μ. The filter media preferably has a gamma value of at least about 14, a surface area of at least about 1.2 m^2/g, and/or an apparent density of at least about 0.15 g/cc. The support layer preferably includes glass fibers having a diameter in the range of about 0.1μ to 30μ. More preferably, the support layer includes chopped glass fibers that have a fiber diameter in the range of about 4μ to 30μ, and more preferably in the range of about 5μ to 12μ, and the filtration layer includes glass wool fibers that have a fiber diameter in the range of about 0.1μ to 4.5μ, and more preferably the diameter of the fibers is in the range of about 0.3μ to 4.5μ. In an exemplary embodiment, the support layer includes glass wool fibers having a diameter in the range of about 3μ to 7μ, and the filtration layer includes glass wool fibers that have a fiber diameter of about 0.69μ and/or 4.5μ. The filtration layer can also optionally include chopped glass fibers, preferably organic fibers, combined with the glass wool fibers. The glass wool fibers are preferably present in the

filtration layer in the range of about 50% to 99% by weight and the chopped glass fibers are preferably present in the filtration layer in the range of about 1% to 50% by weight.

[0008] In other aspects of the present invention, a method of making a filter media formed of or containing one or more nonwoven glass fiber webs is provided. The method includes the steps of preparing a slurry having a pH in the range of about 1 to 12, and more preferably in the range of about 2 to 4, which contains glass wool fibers, chopped glass fibers, water, and an acidic agent, subsequently adding a neutral or alkaline pH adjusting agent to the slurry to adjust the pH to the range of about 6 to 10, and removing the water from the slurry to form a wet laid glass fiber web having a gamma value of at least about 14.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0010] FIG. 1 is a flow chart illustrating an exemplary method of making a filter media according to the present invention;

[0011] FIG. 2A is a photomicrograph at 370X of the filtration layer of a filter media according to the present invention;

[0012] FIG. 2B is a photomicrograph at 370X of the support layer of the filter media shown in FIG. 2A;

[0013] FIG. 3 is a graph illustrating the effect of pH on apparent density;

[0014] FIG. 4 is a graph illustrating the effect of pH on specific resistance;

[0015] FIG. 5 is a graph illustrating the effect of pH on surface area;

[0016] FIG. 6 is a graph illustrating the effect of pH on DOP penetration;

[0017] FIG. 7 is a graph illustrating the effect of pH on Gamma value; and

[0018] FIG. 8 is a photomicrograph at 710X of the filtration layer of a filter media shown in FIGS. 2A and 2B.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention relates to nonwoven glass fiber webs, filter media formed of or containing nonwoven glass fibers webs, and methods of making the same using a wet laid processing technique. The filter media can be used in a variety of applications, including as battery separators, air and water filters, vacuum bag filters, cabin air filters, and indoor air cleaner filters. The filter media are particularly effective, however, for use as pleated filters in clean room environments. The present invention is particularly advantageous in that it has been discovered that adjusting the pH during wet laid processing will produce a glass fiber web having improved filtration properties. In particular, neutralizing the pH of a slurry containing mainly glass wool fibers unexpectedly yields a non-electret, glass filter media that has a gamma value of at least about 14, which is a significant improvement over non-electret, glass filter media currently on the market which have been shown to have a gamma value that does not exceed 13. Moreover, the adjusted pH unexpectedly produces a filter media having an improved surface area, which is preferably at least about 1.2 m^2/g, and an improved apparent density, which is preferably at least about 0.15 g/cc. In an exemplary embodiment, the apparent density of the filter media is in the range of about 0.15 g/cc to 0.21 g/cc.

[0020] The nonwoven glass fiber webs prepared according to the present invention can contain glass wool fibers, or more preferably a combination of glass wool fibers, chopped glass fibers, and optionally other polymeric fibers. The resulting glass fiber web can be used alone, or it can be combined with additional fiber webs, to form a filter media. By way of non-limiting example, suitable fiber webs that can be combined with the glass fiber include polymeric and/or metallic expanded mesh.

[0021] Glass wool fibers are a specific type of fiber that are prepared by blowing or spinning molten glass through small holes. Unlike typical chopped glass fibers, glass wool fibers have a very small diameter, which typically ranges from about 0.1µ up to 4µ or 5µ. In an exemplary embodiment, the nonwoven glass webs are formed from glass wool fibers having a fiber

diameter in the range of about 0.1μ to 4.5μ, and more preferably in the range of about 0.3μ to 4.5μ. In an exemplary embodiment, the glass wool fibers have a fiber diameter of about 0.69μ and/or 4.5μ. The glass wool fibers tend to vary significantly in length, and thus no specific length is required. In an exemplary embodiment, however, the aspect ratio (length to diameter ratio) (l/d) of the glass wool fibers is preferably generally in the range of about 100 to 10,000, more preferably in the range of about 200 to 2500, and most preferably in the range of about 300 to 600. A person having ordinary skill in the art will appreciate that a variety of different glass wool fibers can be used to form a nonwoven glass fiber web according to the present invention.

[0022] As indicated above, the nonwoven glass webs can also include chopped glass fibers that can be combined with the glass wool fibers during processing. The chopped glass fibers can be present in any amount, but are preferably present at about 1% to 30% by weight in a web containing about 70% to 99% by weight glass wool fibers. The chopped glass fibers preferably have a fiber diameter in the range of about 4μ to 30μ, and more preferably about 5μ to 12μ, and a length in the range of about 0.125 inch to 1 inch. In an exemplary embodiment, the nonwoven glass webs contain glass wool fibers having a diameter of about 0.69μ and/or 4.5μ, and chopped glass fibers having a diameter in the range of about 5μ to 7μ.

[0023] The nonwoven glass fiber webs and filter media containing the nonwoven glass fiber webs are formed using a wet laid processing technique, which involves preparing a slurry containing glass wool fibers, chopped glass fibers, and water. The fibers are suspended uniformly in the slurry at very low concentrations in the range of about 0.01 to 0.5% by weight of fiber. Since glass wool fibers are anionic by nature, an acidic agent can be added to the slurry to form a slurry having a pH in the range of about 2 to 4, and most preferably about 3. The pH can, however, be adjusted to a range of about 1 to 12. The acidic agent is also effective to remove the charge on the fibers, thereby improving dispersion of the fibers and facilitating processing of the web. While virtually any acidic agent can be used, sulfuric acid is an exemplary pH reducing agent. Other suitable acidic agents include, for example, hydrochloric acid, formic acid, citric acid, and other mineral and organic acids.

[0024] Once the slurry is prepared and the pH is adjusted to about 3, a neutral or alkaline pH adjusting agent is added to the slurry to adjust the pH to a pH in the range of about 6 to 12, and

more preferably in the range of about 7 to 10. It has been discovered that this additional step of adding a neutral or alkaline pH adjusting agent to the slurry unexpectedly produces a nonwoven glass web having improved filtration properties, as will be discussed in more detail below. Virtually any neutral or alkaline agent can be used to adjust the pH of the slurry. In an exemplary embodiment, ammonium hydroxide is added to the slurry to adjust the pH to about 7. Other suitable alkaline pH adjusting agents include, for example, metal hydroxides, such as potassium hydroxide and sodium hydroxide, calcium bicarbonate, and buffer solutions. After adjusting the pH, the fibers can be collected on a screen and dried to form a nonwoven glass web having one or more layers of glass fibers.

[0025] Wet laid nonwoven glass webs are typically prepared using a papermaking process, which includes a hydropulper, a former or headbox, a dryer, and optionally a converter. As shown in FIG. 1, the original slurry, which contains the glass wool fibers, the chopped glass fibers, an acidic agent, and water, is prepared in the hydropulper (1). The temperature of the slurry is preferably maintained in the range of about 40° F to 100° F, and more preferably in the range of about 50° F to 85°F. After the slurry has been mixed in the hydropulper (1) for about 3-10 minutes, it is pumped into the former or headbox (2), where the neutral or alkaline pH adjusting agent is preferably added. The slurry is also diluted with additional water such that the final concentration of fiber is in the range of about 0.1% to 0.5% by weight. The fibers are then collected on a screen (3) preferably at a rate of in the range of about 20 g/m^2 to 200 g/m^2. Before the slurry is sent to headbox, the slurry is passed through centrifugal cleaners to remove unfiberized glass or shot. The slurry may or may not be passed through additional equipment such as refiners or deflakers to further enhance the dispersion of the fibers. Care must be taken to minimize the work done to the fiber. Glass fibers tend to be very brittle and excess fiber shortening should be avoided. Excess water is removed by gravity and vacuum assisted drainage. A binder can be added to the fiber in the wet web or green state. The wet formed web is then passed over a series of drum dryers (4) to dry at a temperature in the range of about 250° F to 350° F, preferably in the range of about 275° F to 325° F. Typical drying times vary until the moisture content of the composite fiber is less than about 6%.

[0026] In another embodiment, the nonwoven glass webs can be combined with one or more additional fiber layers to form a filter media. The filter media can include any number of layers,

can be formed from a variety of fibers, and can be prepared using a variety of manufacturing methods. By way of non-limiting example, the filter media can be laminated or otherwise attached to an organic or metal backing.

[0027] In an exemplary embodiment, the filter media includes a support layer and one or more layers of a nonwoven glass web deposited onto the support layer to form a filtration layer. The filtration layer(s) are preferably prepared as described above at a pH of at least about 6. The support layer is effective to provide structural integrity to the filter media, and is preferably a wet laid glass fiber web. In an exemplary embodiment, the support layer is formed from chopped glass fibers having a fiber diameter in the range of about 4μ to 30μ, and more preferably about 5μ to 12μ, and the filtration layer(s) are formed from a combination of glass wool fibers having a diameter in the range of about 0.1μ to 4.5μ, and more preferably about 0.3μ to 4.5μ, and chopped glass fibers having a diameter in the range of about 4μ to 30μ, and more preferably about 5μ to 12μ. In an exemplary embodiment, the support layer is formed from chopped glass fibers having a fiber diameter in the range of about 3μ to 7μ, and the filtration layer(s) are formed from a combination of glass wool fibers having a diameter in the range of about 0.69μ and/or 4.5μ and chopped glass fibers having a diameter in the range of about 5μ to 7μ. By way of non-limiting example, FIGS. 2A and 2B are photomicrographs, at 370X, of a filter media according to the invention having a support layer (FIG. 2B) and a filtration layer (FIG. 2A) deposited on the support layer.

[0028] The filter media can be prepared using a variety of techniques, but preferably the support layer is prepared in a slurry and passed through a first headbox where the fibers are collected on a screen. The fibers then travel on the screen to a second headbox, which contains the glass wool/chopped glass fiber combination having a pH of at least about 6. The glass wool / chopped glass fiber mixture is deposited onto the support layer, and the two-layer structure is then dried to form a filter media. The web can optionally be passed through one or more headboxes to add additional layers to the web.

[0029] A person having ordinary skill in the art will appreciate that the glass fibers used according to the present invention, as well as the compositions of these glass components, can be varied to achieve optimal performance depending on the intended use. The nonwoven glass

webs are not intended to be limited to webs formed from only glass wool fibers, but can include a variety of other fiber types in addition to the glass wool fibers and the chopped glass fibers disclosed herein. Preferably, however, the nonwoven glass webs contain a majority of glass wool fibers. The nonwoven glass webs can also include a variety of other ingredients, such as additives, surfactants, coupling agents, crosslinking agents, etc. In one embodiment, the nonwoven glass webs contain a binding agent. The binder coats the fibers and is used to adhere the fibers to each other to facilitate adhesion between the fibers. In general, the binder, if present in the nonwoven web, is in the range of about 2% to 10% by weight, preferably in the range of about 3% to 9% by weight, and most preferably in the range of about 4% to 7% of the total composite weight.

[0030] As previously stated, it has been discovered that neutralizing the pH of the glass fiber slurry during the wet laid process unexpectedly improves filtration efficiency of the resulting filter media. In general, filter performance is evaluated by different criteria. It is desirable that filters, or filter media, be characterized by low penetration across the filter of contaminants to be filtered. At the same time, however, there should exist a relatively low pressure drop, or resistance, across the filter. Penetration, often expressed as a percentage, is defined as follows:

$$Pen = C/C_0$$

where C is the particle concentration after passage through the filter and C_0 is the particle concentration before passage through the filter. Filter efficiency is defined as

$$100 - \%\ Penetration.$$

[0031] Because it is desirable for effective filters to maintain values as low as possible for both penetration and pressure drop across the filter, filters are rated according to a value termed gamma value (γ). Steeper slopes, or higher gamma values, are indicative of better filter performance. Gamma value is expressed according to the following formula

$$\gamma = (-\log(\text{DOP penetration }\% / 100) / \text{ pressure drop, mm}) \times 100$$

The pressure drop across the filter is typically a few mm of H_2O.

[0032] FIGS. 3-7, which will be discussed in more detail below, illustrate the effect of pH on the filtration efficiency. In particular, by neutralizing the pH of the glass fiber slurry to a value in the range of about 6 to 12, and more preferably in the range of about 7 to 10, the resulting filter media has an increased surface area. This increase in the surface area eliminates the need to add additional microfibers having a diameter in the range of about 0.1μ to 0.5μ during manufacturing of the filter media. Sub-micron fibers having a very small diameter, e.g., around 0.5μ, typically tend to wash through the screen during the wet laid process. Thus, some conventional techniques attempt to compensate for this loss by adding additional sub-micron fibers to the slurry during the wet laid process to compensate for the loss. Microfibers with a sub-micron fiber diameter are very expensive, however, and thus their excessive use is undesirable. By neutralizing the pH of the slurry to at least about 6, the sub-micron sized fibers appear to remain in the resulting filter media. This is illustrated in FIG. 8, which shows a photomicrograph, at 710X, of a filter media according to the invention having submicron sized fibers therein. An additional advantage of retaining sub-micron fibers in the resulting filter media is that the surface area of the filter media is significantly increased.

[0033] FIGS. 3-7 show graphs illustrating the effect of pH on filtration properties. The graphs were prepared using data was obtained through test run on samples prepared as follows:

Example 1

[0034] A slurry was prepared containing 50 lbs. of Evanite 706X fiber having an average fiber diameter of about 0.69μ, 30 lbs. of Evanite 712X fiber having an average fiber diameter of about 4.2μ, 3 lbs. of Owens-Corning Chopped Glass fiber DE having an average fiber length of about 0.25 inches, and 3 lbs. of Owens-Corning Chopped Glass fiber DE having an average fiber length of about 0.5 inches. The slurry contained water and sulfuric acid sufficient to yield a fiber concentration of 0.75% by weight. The headbox pH was varied between 2.3 and 3.8, and the samples of web were collected at a headbox pH of 3.8, 3.6 and 2.3. The experiment was repeated containing the same fiber formulation combined with water and ammonium hydroxide to vary the headbox pH between 4.3 and 10.3. Samples were collected at a headbox pH of 10.4, 9.6, 9.2, 8.4, 7.0, 6.0 and 4.2. The properties of each sample were tested and are shown in the

chart below. All tests were conducted at an air velocity of 5.33 cm/sec with a DOP particle size of 0.3 microns.

Table 1

pH	DOP (%)	Resistance (mmH_2O)	Ream Weight (lbs)	Specific Resistance (mm/lb)	Caliper (mm @ 10Kpa)	Apparent Density (g/cc)	Surface Area (sq.m/g)	Gamma (TDA100P)
2.3	0.297088	22.31	42.8	0.5213	0.331	0.21	n/a	13.115
3.6	0.4116	20.88	44.4	0.4703	0.358	0.202	n/a	13.57
3.8	0.173885	24.26	50	0.4853	0.403	0.202	n/a	13.283
4.2	0.181495	23.54	47.1	0.4997	0.380	0.202	1.2517	13.42
6.0	0.02003	29.39	47.9	0.6135	0.425	0.184	1.4488	14.475
7.0	0.004853	32.64	48.8	0.6689	0.433	0.1845	1.5174	15.083
8.0	0.001248	37.23	49.9	0.7461	0.462	0.176	n/a	15.03
8.4	0.001883	35.90	49.7	0.7224	0.461	0.176	1.5596	16.037
9.2	0.002668	34.74	48.8	0.7119	0.473	0.168	n/a	16.055
9.6	0.001552	36.79	51.5	0.7143	0.510	0.164	1.9726	15.615
10.4	0.00291	34.36	48.2	0.7128	0.451	0.174	n/a	16.76

[0035] As shown in Table 1 and in FIGS. 3-7, filter media prepared from a slurry having a pH, adjusted at the headbox, of at least about 6, advantageously show improved filtration properties. FIG. 3 illustrates the effect of pH on the apparent density of the filter media. A lower density is desirable since the filter media will have more loft and thus a longer path for the dust particle to travel through the filter media. This resulted in increasing probability of the dust particles being intercepted by a fiber. As shown, samples having a pH in the range of about 1 to 5 have an apparent density greater than 0.202 g/cc, while filter media having a pH above 6 show a drop in the apparent density to 0.184 g/cc or less.

[0036] Adjusting the pH during processing of glass fibers webs also significantly improves the specific resistance of the web. Specific resistance is tested by blowing air through the web at a particular velocity and measuring the pressure drop across the web. A fiber web having a high specific resistance is preferred, as the filter media is more effective to capture small particles. FIG. 4 illustrates the effect of pH on specific resistance. As shown, webs produced with a pH between 2 and 5 yield a filter media have a specific resistance around 0.5 mm/lb, while webs

produced having a pH of at least about 6 have a specific resistance of at least about 0.6 mm/lb or greater. Fiber webs produced at a pH in the range of about 8 to 10 yield filter media which show an even greater increase in specific resistance to about 0.7 mm/lb or greater.

[0037] FIG. 5 illustrates the effect of pH on surface area, and in particular that a change in pH from about 4 to about 6 or more significantly increases the surface area of the resulting filter media. In particular, as shown, the surface area of filter media produced from a slurry having a pH of about 4.2 is about 1.25, while the surface area of filter media produced from a slurry having a pH of about 6 or more significantly increases to at least 1.44 or greater.

[0038] FIG. 6 illustrates the effect of pH on DOP penetration, which is tested by blowing DOP particles through a filter media and measuring the percentage of particles that penetrate through the filter. A low DOP penetration is desirable since more particles are captured by the filter. As shown in FIG. 6, webs produced at a pH around 2 or 3 yield filter media having a DOP penetration in the range of about 0.3% to 0.4%, and webs produced at a pH around 4 have a DOP penetration of about 0.18%. Conversely, webs produced at a pH of 6 or more yield filter media that show a significant decrease in the DOP penetration to about 0.03% or less. Filter media having a DOP penetration of 0.02% or less are effective for use in HEPA filters, and filter media having a DOP penetration of 0.001 or less are effective for use in ULPA filters. Thus, by increasing the pH to at least about 6, filter media prepared according to the present invention can advantageously be effective for use in HEPA and ULPA filters.

[0039] FIG. 7 illustrates the effect of pH on Gamma value, which is a measure of filtration efficiency, as previously discussed. The Gamma value can be tested using a TDA 100P. As used herein, the Gamma value refers to the value tested using Aerosol Penetrometer, Model TDA-100P manufactured by Ait Techniques, Owings Mills, Maryland. Again, webs produced at a pH of 6 or greater yield filter media that show a significant increase in Gamma value. In particular, webs produced at a pH in the range of about 2 and 4 yield filter media that show a TDA 100P tested Gamma value of about 13, while webs produced at a pH greater than about 6, and more preferably greater than about 7, yield filter media that show an Aerosol Penetrometer tested Gamma value of at least about 14.

[0040] Accordingly, FIGS. 3-7 illustrate a significant, unexpected increase in filtration properties as a direct result of controlling pH during web processing. Nonwoven glass fiber webs produced at a pH of at least about 6, and more preferably in the range of about 7 to 10, yield filter media that show a significant increase in apparent density, specific resistance, surface area, DOP penetration, and Gamma value.

Example 2

[0041] A slurry was prepared containing 50 lbs. of Evanite 706X fiber having an average fiber diameter of about 0.69μ, 30 lbs. of Evanite 712X fiber having an average fiber diameter of about 4.2μ, 6 lbs. of Owens-Corning Chopped Glass fiber DE having an average fiber length of about 0.25 inches, and 1.7 lbs. of 1.7 denier Polyester fiber having an average fiber length of about 0.25 inches. The slurry was prepared in a hydropulper with a fiber concentration of about 2.7% and a pH at about 9. The slurry was then transferred to a storage tank containing additional water. The fiber concentration in the storage tank was about 0.7%, and the pH was about 9.0. The slurry was then fed from the storage tank into the headbox to yield a fiber concentration less than about 0.2%. The headbox was maintained at a pH of 9.2 and a sample of web was collected. The headbox pH was then adjusted to 3.6 and 3.4 by the addition of sulfuric acid, and samples of web were collected at a headbox pH of 3.6 and 3.4. The experiment was repeated containing the same fiber formulation combined with water and ammonium hydroxide to vary the headbox pH between 4.1 and 8.2. Samples were collected at a headbox pH of 4.1, 6.6, 7.4, and 8.2. The properties of each sample were tested and are shown in the chart below. The apparent density was determined according to the following formula:

$$\frac{\underline{\text{basis wt. } (g/m^2)\ /\ \text{caliper @ 10Kpa (mm)}}}{1000}$$

Table 2

pH	DOP (%)	Resistance (mmH_2O)	Gamma (TDA 100P)	Basis Weight (lbs)	Caliper (mm @ 10Kpa)	Apparent Density (g/cc)
9	0.0003	34	16.24	47.28	0.4708	0.162
9	0.0003	32.9	16.79	n/a	n/a	n/a
9.1	0.0026	29	15.84	45.59	0.4295	0.172
9.1	0.0023	29.5	15.72	n/a	n/a	n/a
9.2	0	36.4	n/a	50.58	0.4748	0.173
9.2	0	36.1	n/a	n/a	n/a	n/a
9.3	0.0078	25.5	16.1	n/a	n/a	n/a
9.3	0.0079	25.8	15.9	n/a	n/a	n/a
3.6	0.38	17.2	14.07	36.53	0.3	0.197
3.6	0.4	17.2	13.94	n/a	n/a	n/a
3.4	0.33	17.3	14.34	34.11	0.274	0.202
3.4	0.36	17.4	14.07	n/a	n/a	n/a
4.1	0.17	19	14.57	37.60	0.3133	0.194
4.1	0.16	19.2	14.56	n/a	n/a	n/a
5	0.085	20.4	15.05	36.63	0.3283	0.181
5	0.078	20.7	15.01	n/a	n/a	n/a
6	0.012	25.4	15.44	37.89	0.355	0.173
6	0.011	25.3	15.64	n/a	n/a	n/a
6.9	0.0022	29.2	15.95	39.81	0.3715	0.174
6.9	0.0017	29.2	16.33	n/a	n/a	n/a
7.4	0.0013	29.1	16.79	39.18	0.3735	0.17
7.4	0.002	29.1	16.15	n/a	n/a	n/a
8.2	0.0027	28.8	15.86	41.12	0.3965	0.168
8.2	0.0027	28.6	15.97	n/a	n/a	n/a

Example 3

[0042] A two layer fiber web was prepared. The first layer was formed from a slurry containing 10 lbs. of Evanite 706X fiber having an average fiber diameter of about 0.69μ, 50 lbs. of Evanite 712X fiber having an average fiber diameter of about 4.2μ, 12.5 lbs. of Owens-Corning Chopped Glass fiber DE having an average fiber length of about 0.25 inches, and 2.1 lbs. of cellulose pulp. The cellulose pulp was refined to a Canadian standard freeness number of less than 200. The

first layer was collected from a headbox at a pH of about 3.2 to 3.3. The second layer was formed from a slurry containing 50 lbs. of Evanite 706X fiber having an average fiber diameter of about 0.69μ, 6.25 lbs. of Owens-Corning Chopped Glass fiber DE having an average fiber length of about 0.25 inches, and 0.56 lbs. of cellulose pulp. The second layer was collected on the first layer from a headbox at a pH of about 7.0. Each layer had a basis weight in the range of about 34 to 37 g/m^2 by weight. The properties of each sample were tested and are shown in the chart below.

Table 3

Basis Weight	74 g/m^2 (TAPPI T-410 om-98)
Thickness	0.371 mm
Apparent Density	0.199 g/c.c.
DOP penetration	0.010%
Resistance	26.1 mm
Gamma (TDA 100P)	15.3
Stiffness – Machine Direction	286 mg (TAPPI T-410 om-98)

[0043] One of ordinary skill in the art will appreciate further features and advantages of the invention based on the above-described embodiments. Accordingly, the invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety.

[0044] What is claimed is: